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(54) Title: AGENTS AND METHODS FOR PROTECTION, TREATMENT AND REPAIR OF CONNECTIVE TISSUE (57) Abstract The present invention relates to compositions for the protection, treatment and repair of connective tissues in humans and animals comprising any or all of anabolic, anti-catabolic, and anti-oxidant agents, including aminosugars, S-adenosylmethionine, arachadonic acid, GAGs, pentosan, collagen type II, tetracyclines or tetracycline-like compounds, diacerin, super oxide dismutase, and L-ergothionine and to methods of treating humans and animals by administration of these novel compositions to humans and animals in need thereof.		

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'AGENTS AND
METHODS FOR PROTECTION, TREATMENT AND REPAIR OF CONNECTIVE TISSUE.'

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Field of the Invention:

The present invention relates to compositions for the protection,
10 treatment and repair of connective tissues in humans and animals.

Background of the Invention:

The tissues of mammals, including humans, are in a constant state of
flux between the anabolic processes that build up tissues, and the catabolic processes
which degrade tissues. The state of health exists when there is a balance between these
15 two processes, and derangements of the balance produce disease. This holds true for all
tissues of the body. Connective tissues are of particular importance for several reasons.
First, they support the "functional cells" of the body, i.e., epithelial, muscle and neural
cells. Second, they play critical roles in intercellular communication, which is essential
for multicellular life.

20 The inflammatory process occupies a key position in this balance.
When injury to tissues occurs, inflammation initiates the biochemical processes that
result in tissue repair. Because inflammation results in the symptoms of pain,
inflammation, and swelling of the tissues involved, it is often regarded by both patients
and physicians as an abnormal and undesirable state, which should be treated and
25 relieved as soon and as completely as possible. As a result, pharmacies are full of
"anti-inflammatory drugs" (such as corticosteroids and the non-steroidal anti-

inflammatory drugs, such as aspirin). Under certain circumstances, inflammation can indeed be destructive; however, it is important to remember that inflammation is closely linked with tissue healing. Indeed, inflammation is not easily categorized as strictly anabolic or catabolic -- it may have either effect. Its purpose in the body is to
5 remove, dilute or wall-off the injurious agent(s). It also sets into motion the biochemical processes that repair and reconstruct the damaged tissue. Because it is essential to healing, and because it can also cause tissue destruction, inflammation and its mediators are important factors in the anabolic and catabolic balance.

One very important class of inflammatory mediators is the eicosanoid
10 group. The eicosanoids are synthesized in the body from essential fatty acids ("Fas"). Through a series of biochemical reactions, the precursor fatty acids are modified to produce intermediate metabolites, arachadonic acid ("AA"), an omega-6 FA; and eicosapentanoic acid ("EPA"), an omega-3 FA. Eicosanoids produced from arachidonic acid include the 2-series of prostaglandins and the 4-series of leukotrienes,
15 which are generally proinflammatory. The eicosanoids derived from EPA, such as the 3 series prostaglandins and hydroxyeicosapentaenoic acid ("HEPE"), are less inflammatory than those derived from AA. In addition, such eicosanoids may even have anti-inflammatory effects.

As a class, the eicosanoids are short-lived and locally active. They are
20 responsible for the initial events of inflammation, including vasodilation, increased vascular permeability, and chemotaxis. Moreover, the eicosanoids are instrumental in the early steps of the healing process. For example, the eicosanoids trigger the release of cytokines such as TGF- β , which in turn stimulates the migration and proliferation of connective tissue cells, and the deposition of extracellular matrix. Specific constitutive
25 eicosanoids also have protective effects in the gastrointestinal mucosa and kidney,

because they maintain glycosaminoglycan synthesis and normal perfusion of these organs.

Because of anabolic processes such as these, and because of the influence of natural anti-catabolic and anti-oxidant agents in the body, the outcome of the majority of cases of inflammation is resolution of the injury and healing of the damaged tissues. Only in pathologic situations does inflammation itself become a contributor to disease.

Research on the therapeutic use of eicosanoid precursor FAs (including cis-linoleic and alpha-linolenic acids, the so-called omega-3 and omega-6 fatty acids) has been primarily directed towards their use as competitive inhibitors of the synthesis of eicosanoids, and therefore, their anti-inflammatory effects. Except in cases of severe or absolute dietary deficiency, little attention has been given to the beneficial, anabolic effects that the eicosanoids have in connective tissues. However, naturally occurring "subclinical" deficiencies of eicosanoids probably contribute significantly to disease, and are under diagnosed. For example, the enzyme delta-6-desaturase is responsible for the committed step in the synthesis of AA. Activity of this enzyme, (delta-6-desaturase) decreases with age. This is likely to prove a significant factor in the increased incidence of connective tissue dysfunction in older population segments since a deficiency of AA would decrease anabolic processes and allow catabolic events to dominate.

Given the importance of inflammation in the healing of tissues, and the protective role that some eicosanoids play, it is not surprising that pharmaceuticals that decrease inflammation by blocking eicosanoid production should also have negative effects on healing and anabolic processes. It has long been known that corticosteroid drugs, which are strongly anti-inflammatory, also delay healing and decrease the

production of extracellular matrix components. This is because cortisol and related compounds stabilize cell membranes and therefore inhibit the release of phospholipase A2, the precursor of AA. Recently attention has turned to the non-steroidal anti-inflammatory drugs ("NSAIDs"). Numerous studies have shown that NSAIDs, like corticosteroids, can decrease the synthesis of matrix components by connective tissue cells, because they inhibit prostaglandin endoperoxide synthase, and thus block the cyclooxygenase pathway.

Since the inflammatory process is the *sine qua non* of tissue healing, and since the eicosanoids are the mediators of the inflammatory process, the use of AA (and other eicosanoid compounds) is a novel approach to therapy of injured tissues.

Kirkpatrick et al. investigated the use of prostanoid precursors on chick embryonic cartilage in organ culture and found no significant effects. [Kirkpatrick, C.J., "Effects of Prostanoid Precursors and Indomethacin on Chick Embryonic Cartilage Growth in Organ Culture," Expl. Cell Biol., 51:192-200 (1993)]. The experimental model in this work may have contributed to the absence of significant effects, because avian cartilage and embryonic cartilage differ significantly from mammalian, postnatal cartilage. For example, embryonic cartilage of any species is hypermetabolic and anabolic to begin with because it is in a period of exponential growth. Kent et al. examined the effects of AA in lapine cartilage and found a positive effect, although previous and subsequent research failed to confirm this. [Kent, L. et al., "Differential Response of Articular Chondrocyte Populations to Thromboxane B2 and Analogs of Prostaglandin Cyclic Endoperoxidases," Prostaglandins, 19:391-406 (1980)]. Kirkpatrick and Gardner found that AA and various metabolites of AA had insignificant or inhibitory effects on biosynthesis. [Kirkpatrick C.J. and Gardner, D.L., "Influence of PGA1 on Cartilage Growth," Experientia, 33(4):504 (1976)]. These variable results are not unexpected.

since the balance between anabolic and catabolic processes in the body is delicate and easily perturbed. Phan et al., suggest that products of AA via the cyclooxygenase pathway are anti-fibrogenic while AA products via the lipoxigenase pathway are pro-fibrogenic. This phenomenon demonstrates the complexity of the eicosanoids'

5 interactions.

Catabolic events are typically mediated in the body by enzymes that break apart body constituents. Catabolism is essential for health and deficiency of necessary enzymes results in disease, such as the so-called storage diseases like mucopolysaccharhidosis. Excessive catabolism may also result in the breakdown of
10 tissues and lead to disease, as in degenerative diseases like osteoarthritis or autoimmune diseases like multiple sclerosis. Various anti-catabolic substances in the body help contain and balance catabolism. For example, chondroitin sulfate counteracts metalloproteinases that catabolize collagen and proteoglycans in the cartilage matrix. Similarly, alpha-one anti-trypsin inhibits the effects of elastase, which
15 contributes to alveolar breakdown in emphysema.

Oxidative damage also has an impact on the balance of anabolism and catabolism in the body. This damage is the result of the effects of free radicals, substances that have an unpaired electron. Free radicals form constantly in the body as the result of normal reactions like the production of ATP. They also form during the
20 inflammatory process. Free radicals cause cellular damage because they are highly chemically reactive. Because they have only a single electron, (a condition that nature abhors as it does a vacuum), these substances "steal" electrons from molecules in their vicinity. The molecules making up cell structures, such as the cell membrane or DNA are thereby rendered electron-deficient. The deficiency of electrons in turn makes the
25 cell structure unstable and cell dysfunction occurs, including manufacture of abnormal

proteins, cell rupture, and cell death. Oxidative damage is implicated in many catabolic events in the body, including the aging process. Anti-oxidants, such as vitamin C, vitamin E, superoxide dismutase (SOD), selenium, and glutathione are substances that scavenge free radicals before oxidative damage occurs. In the sense that they prevent
5 cell damage, anti-oxidants are a specific type of anti-catabolic agent.

The body also contains anabolic compounds that stimulate tissue growth. Glucosamine is an amino sugar naturally formed in the body from glucose. When supplied exogenously, glucosamine stimulates connective tissue cell synthesis, and thereby increases the amounts of normal extracellular matrix. Glucosamine is also
10 the building block for glycosaminoglycans in cartilage and other connective tissues. Supplying additional glucosamine thus supplies the body with extra raw materials for matrix synthesis in connective tissues. Other examples of anabolic compounds in the body include somatotropin, which stimulates protein synthesis, and the somatomedins or insulin-like growth factors, which stimulate the proliferation of chondrocytes and
15 fibroblasts and enhance matrix synthesis.

The actions and interactions of these compounds are complex. A given compound may have different effects in different tissues. For example, somatotropin increases protein synthesis (anabolism), but also speeds fat breakdown (catabolism). The effects that a particular compound or combination of compounds will have depend
20 on many factors, including route of administration, dosage, and duration of therapy.

Previous researchers have investigated the use of individual compounds for their anabolic, anti-oxidant or anti-catabolic effects. Glucosamine has been found in cell culture to stimulate connective tissue cells to produce the components of the matrix: collagen and glycosaminoglycans (GAGs). [Jimenez, S., "The Effects of
25 Glucosamine sulfate on Chondrocyte Gene Expression," Eular Symposium, Madrid

October 1996 Proceedings, page 8-10]. S-adenosylmethionine is known to participate in several synthesis reactions, including the sulfation of GAGs. [Champe, P.

Biochemistry, 2nd edition, J.B. Lippincott Co, Philadelphia, 1994, pp. 248, 250, 265].

Arachadonic acid has been found to stimulate corneal healing. [Nakamura, M.,

5 "Arachidonic Acid Stimulates Corneal Epithelial Migration", J. Ocul. Pharmacol.,

Summer:10(2): 453-9 (1994)]. These compounds therefore have anabolic effects.

Chondroitin sulfate has been shown to inhibit degradative enzymes,

including the metalloproteinases that destroy cartilage matrix. [Bartolucci, C.,

"Chondroprotective action of chondroitin sulfate," Int. J. Tiss. Reac., XIII(6):311-317

10 (1991)]. Studies with pentosan sulfate have shown that it prevents complement-

mediated damage in a rabbit myocardial cells. [Kilgore, K., "The Semisynthetic

Polysaccharide Pentosan Polysulfate Prevents Complement-Mediated Myocardial

Injury in the Rabbit Perfused Heart," J. Pharmacol. Exp. Ther., 285(3):987-94 (1998)].

Oral administration of collagen type II has been shown to decrease the deleterious

15 immune response that destroys joint tissue in rheumatoid arthritis. Tetracycline

analogues are potent inhibitors of matrix metalloproteinases. [Ryan, M., "Potential of

Tetracyclines to Modify Cartilage Breakdown in Osteoarthritis." Curr. Opin.

Rheumatol., 8(3): 238-47 (1996)]. Diacerein modifies the inflammatory process by

inhibiting interleukin-1 activity, and also by direct effects on lymphocytes and

20 neutrophils. [Beccerica, E., "Diacetylrhein and rhein: in vivo and in vitro effect on

lymphocyte membrane fluidity," Pharmacol. Res., 22(3):277-85 (1990): Mian, M.,

"Experimental Studies on Diacerhein: Effects on the Phagocytosis of Neutrophil Cells

from Subcutaneous Carregeenan-Induced Exudate." Drugs Exp. Clin. Res., 13(11):695-

8 (1987); Spencer, C., "Diacerein", Drugs, 53(1):98-106 (1997)]. These compounds

25 can be classed as anti-catabolic agents.

L-ergothionine scavenges hydroxyl radicals and may inhibit singlet oxygen formation. [Han JS. "Effects of Various Chemical Compounds on Spontaneous and Hydrogen Peroxide Induced Reversion in Strain TA104 of *Salmonella typhimurium*." Mutant Res., 266(2):77-84 (1992)], while superoxide dismutase scavenges superoxide radicals [Mathews C., Biochemistry 2nd ed., Benjamin/Cummings Pub. Co., Menlo Park CA, 1996, page 551]. These compounds can be classified as anti-oxidants.

Although these compounds have been investigated individually, to our knowledge no one other than the present inventors has examined the effects of certain combinations of any or all of anabolic, anti-catabolic and anti-oxidant agents to maintain health and to promote healing. According to the present invention, combinations of these agents can be used to maximize appropriate anabolic effects (healing) and decrease undesirable catabolic effects (degradation) and oxidative damage, while at the same time, causing minimal or no adverse reactions. Therefore, it can be seen that there exists a need to provide compositions that will make use of the beneficial effects of combinations of anabolic agents, anti-catabolic agents and anti-oxidant agents for the maintenance and repair of connective tissues in humans and animals.

20 Summary of the Invention:

The present invention provides novel compositions and methods of treating repairing, and preventing damage to connective tissues in humans and animals using such compositions. Therefore, it is an object of the invention to provide novel compositions of any or all of anabolic, anti-catabolic, and anti-oxidant agents for the protection, treatment and repair of connective tissues in humans and animals.

It is another object of the present invention to provide methods of treating and repairing connective tissue in humans and animals with compositions containing any or all of anabolic, anti-catabolic, and anti-oxidant agents.

It is still another object of the present invention to provide compositions
5 any or all of anabolic, anti-catabolic, and anti-oxidant agents selected from the group consisting of aminosugar, S-adenosylmethionine (SAME), arachadonic acid (AA), GAG, pentosan sulfate, collagen type II, tetracyclines, diacerin, super oxide dismutase (SOD), and L-ergothionine.

It is a further object of the present invention to provide compositions to
10 repair, treat, and prevent damage to connective tissue in humans and animals that contain one or more of the elements selected from the group consisting of aminosugar, SAME, arachidonic acid, GAG, pentosan sulfate, collagen type II, tetracyclines, diacerin, SOD, and L-ergothionine.

These and other objects of the present invention are apparent from the
15 detailed description and claims below.

Brief Description of the Drawings

Figure 1 provides a detailed description of the biosynthetic pathway for the creation of GAGs such as chondroitin sulfate.

Figure 2 is the molecular structure of SAME and its immediate
5 precursor.

Figure 3 provides a simplified diagram of the function of SOD.

Detailed Description of the Invention:

The compositions of the present invention, used to treat, repair, and
10 prevent damage to connective tissue, consist of anabolic, anti-catabolic, and anti-oxidant agents selected from the group consisting of glucosamine, SAME, AA, chondroitin sulfate, pentosan sulfate, collagen type II, tetracyclines, diacerin, SOD, and L-ergothionine. In addition, the present invention covers methods of administering these novel compositions to humans and animals in need thereof.

15 Glucosamine -- an example of an aminosugar -- is naturally formed in the body from glucose. When supplied exogenously, glucosamine stimulates connective tissue cell synthesis, increasing the amounts of normal extracellular matrix. Glucosamine is also the building block for glycosaminoglycans ("GAGs") in cartilage and other connective tissues, thus, supplying additional glucosamine supplies the body
20 with extra raw materials for matrix synthesis in connective tissues. The aminosugar component of the compositions of the present invention may comprise natural, synthetic or semi-synthetic aminosugars including but not limited to salts of glucosamine including glucosamine hydrochloride and glucosamine sulfate, and N-acetylglucosamine and salts and/or mixtures thereof. In addition, the term aminosugar is also used herein to
25 encompass aminosugars that may have been chemically modified yet retain their function.

Such chemical modifications include but are not limited to esterification, sulfation, polysulfation, acetylation, and methylation. Moreover, it is contemplated that the term aminosugar can extend to any composition of matter that is insubstantially different from the aminosugar as above-described.

5 The GAG component of the compositions of the present invention may comprise natural, synthetic or semisynthetic GAGs, GAG-like compounds, or GAG precursors, including but not limited to chondroitin, hyaluronic acid, glucuronic acid, iduronic acid, keratan sulfate, heparan sulfate, dermatin sulfate, and fragments, salts, and mixtures thereof. In addition, the term GAG as used herein further encompasses GAGs
10 that have been chemically altered yet retain their function. Such modifications include but are not limited to esterification, sulfation, polysulfation, and methylation. In fact, sulfated GAGs are a preferred component of the compositions of the present invention. Hence, mono-sulfated and polysulfated (or oversulfated) GAGs are preferred GAG components of the compositions of the present invention. The term GAGs also is intended to
15 encompass alternative nomenclature for the same group of above-described compounds -- e.g., mucopolysaccharides, proteoglycans, and heparanoids. In addition, the GAG or GAG-like component of the compositions of the present invention may be derived from plant or animal sources, including but not limited to beechwood tree, to forms of animal cartilage including shark cartilage, bovine trachea, whale septum, and porcine nostrils, and
20 to invertebrates such as *Perna canaliculus* and sea cucumber.

Chondroitin sulfate is a preferred GAG. Chondroitin sulfate is the most abundant glycosaminoglycan in articular cartilage and is also present in many other connective tissues in the body. Additionally, chondroitin sulfate competitively inhibits degradative enzymes that degrade connective tissues under conditions of abnormal,
25 excessive inflammation. Chondroitin sulfate is a polymer composed of repeating units

of glucuronic acid and sulfated galactosamine. [Lester M. Morrison, M.D. and O. Arne Schjeide, Ph.D., Coronary Heart Disease and the Mucopolysaccharides (Glycosaminoglycans) 12 (1974); Philip C. Champe and Richard A. Harvey, Lippincott's Illustrated Reviews: Biochemistry, 148-50 (2nd ed. 1994)]. One of

5 ordinary skill in the art understands that chondroitin sulfate must have at least two, and potentially many, of these repeating units of glucuronic acid and sulfated galactosamine.

Figure 1 provides a detailed description of the biosynthetic pathway for the creation of GAGs, such as chondroitin sulfate. In addition, the present invention
10 may include fragments of GAGs, such as fragments of chondroitin sulfate. One of ordinary skill in the art at the time the invention understands that "fragments of glycosaminoglycans" are groups of saccharides that constitute less than two repeating units of the glycosaminoglycan. Hence, it is understood that fragments of these substances would be composed of groups of saccharides that constitute fewer than two
15 of the repeating units of the respective polymer.

For example, one of ordinary skill in the art understands that fragments of chondroitin sulfate are molecules composed of the saccharides that comprise the repeating units of chondroitin sulfate, but that are present in groups of less than the two repeating units described above. Thus, a molecule composed of a glucuronic acid and sulfated
20 galactosamine would constitute a fragment of chondroitin sulfate. Indeed, there are eight different disaccharide structures that may constitute fragments of chondroitin sulfate. [Timothy E. Hardingham and Amanda J. Fosang, Proteoglycans: Many Forms and Many Functions, FASEB J., 6:861-862 (1992)].

Other naturally occurring glycosaminoglycans may be used in this
25 invention, for example, hyaluronic acid. Also, fragments of the glycosaminoglycans

may also be utilized. A person of ordinary skill in the art understands the terms "fragments of chondroitin," "fragments of chondroitin sulfate," "fragments of chondroitin salts," "fragments of glycosaminoglycan" and "chondroitin sulfate fragments," and further understands them to mean groups of saccharides (or salts thereof) that constitute less than two repeating units of the glycosaminoglycan.

One of skill would expect that fragments of chondroitin sulfate, for example, would have the same utility as chondroitin sulfate itself. Chondroitin sulfate is broken down into smaller units within the body, and that it is reformulated in the production of cartilage and other connective tissue. Therefore, it is understood that the body utilizes fragments of chondroitin sulfate in the same manner as it utilizes chondroitin sulfate itself. The same is true with respect to "fragments of chondroitin," "fragments of chondroitin salts," and "fragments of glycosaminoglycan." Each of chondroitin, chondroitin salts and other glycosaminoglycans, if ingested, is broken down by the body and reformulated in the production of cartilage and other connective tissue. Therefore, the body utilizes fragments of chondroitin in the same manner as it utilizes chondroitin itself, utilizes fragments of chondroitin salts in the same manner as it utilizes chondroitin salts, and utilizes fragments of glycosaminoglycans in the same manner as it utilizes glycosaminoglycans

Moreover, it is intended that the term GAG can extend to any composition of matter that is insubstantially different from the GAGs as above-described. An example of such a GAG-like compound that is within the scope of the present invention is pentosan polysulfate (PPS) as well as salts thereof such as calcium-derived PPS and sodium PPS. Accordingly, a preferred GAG-like compound that may be used in the compositions of the present invention is PPS.

PPS is a semi-synthetic polysulfated xylan that is a sulfated form of a compound extracted from beechwood hemicellulose consisting of repeating units of (1-4) linked β -D-xylano-pyranoses. More specifically, PPS is produced by extracting these hemicellulose compounds via a series of chemical reactions from the wood, and then
5 adding numerous sulfate groups to the purified polysaccharide chains. This process results in low molecular weight linear polysaccharide chains that carry numerous negatively charged sulfate groups. PPS is a semi-synthetic heparinoid that is considered an oversulfated form of a GAG.

There are several forms of PPS that display the above-described activities.
10 Sodium PPS and a calcium-derived PPS (called CAPPS) may both be used to accomplish the functions of PPS. Each of these forms of PPS exhibit GAG-like activity, and will hereinafter be referred to as GAG-like compounds.

Pentosan's mechanism of action can be summarized as follows:

1. Anti-inflammatory activities through stabilization and improvement of micro-
15 circulation in the inflamed tissues and through anti-Complement effects (decreases the release of the humoral mediators of inflammation called the Complement cascade).
2. Inhibition of chemotaxis of granulocytes, which are white blood cells that contribute to inflammation.
- 20 3. Stimulatory effect on proteoglycan synthesis.
4. Stimulatory effects on hyaluronic acid synthesis by synovial fibroblasts.
5. Potent inhibition of catabolic enzymes including, human granulocyte elastase (noncompetitive inhibition), hyaluronidase (competitive inhibition), chondroitin-4-

sulfatase and N-acetyl-glucosaminidase at concentrations much more lower than that of NSAIDs.

Other synthetic or semi-synthetic glycosaminoglycans or glycosaminoglycan-like compounds, such as polysulfated glycosaminoglycans, may be used in this invention.

5 Diacerein, a recently recognized organic compound found in plants of the genus *Cassia* has anti-inflammatory effects through inhibition of interleukin-1 β ; consequently collagenase production in articular cartilage is reduced. It reduces the fibrinolytic activity of synovial fibroblasts as well. It also dose-dependently inhibits chemotaxis (attraction of white blood cells) and superoxide anion production (this is
10 one of the "toxic oxygen species" or "free radicals"). These harmful compounds occur spontaneously in the body, especially during destructive inflammation. Diacerein has analgesic and antipyretic activities. It reduces the turnover of chondroitin-4-sulfate resulting in a decrease in the ratio of chondroitin-6-sulfate to chondroitin-4-sulfate. (This ratio is pathologically increased in arthritic joints.) It mildly increases
15 prostaglandin synthesis, which allows it to have protective effects on the gastric mucosa.

S-adenosylmethionine (SAME) is an important endogenous compound, present throughout the body, and taking part in a great number of biologic reactions such as transsulfation reactions. In this role it is an important reactant in the synthesis
20 of many structural components of connective tissues, including proteins and proteoglycans. Thus, SAME has significant anabolic effects which would enhance the actions of other anabolic agents. SAME also has anti-inflammatory effects by virtue of its antioxidant action.

SAMe is compound synthesized in the body from adenosine triphosphate ("ATP") and methionine (Fig. 2). It is present in many tissues, including the central nervous system. The primary CNS function of SAMe is to donate methyl groups in the reactions synthesizing various crucial compounds, including neurotransmitters and phospholipids. For example, SAMe facilitates the conversion of phosphatidylethanolamine to phosphatidylcholine, which forms part of the inner, lipid layer of the plasma membrane. In so doing, SAMe increases membrane fluidity and enhances effectiveness of receptor/ligand binding. [Champ and Harvey, *Biochemistry*, 1994; Stramentinoli, G., "Pharmacologic Aspects of S-Adenosylmethionine," American J. Med., **83**(5A):35 (1987); Baldessarini, F., "Neuropharmacology of S-Adenosyl Methionine," American J. Med., **83**(5A):95 (1987); Carney, M., "Neuropharmacology of S-Adenosyl Methionine," Clin. Neuropharmacol., **9**(3):235 (1986); Janicak, P., "S-Adenosylmethionine in Depression," Alabama J. Med. Sci. **25**(3):306 (1988)]. These functions may also pertain to other methyl donors such as betaine (trimethylglycine), 5-methyltetrahydrofolate, folic acid, and dimethylglycine. [Champ and Harvey, Biochemistry, 1994].

Superoxide dismutase is an enzyme present naturally in the tissues of animals, which has recently been investigated as an agent in the management of inflammation. It acts by intercepting toxic oxygen radicals in the intracellular space during destructive inflammatory processes. It does not inhibit prostaglandin biosynthesis, but stops the overproduction of prostaglandins resulting from destructive inflammation. Some of its effects include inhibition of edema formation and inhibition of acute signs of inflammation and the secondary articular changes (stiffness and calcification) in adjuvant-induced arthritis. Having no analgesic effects, it does not contribute to the overuse of the affected joints that eventually leads to more damage of

the articular cartilage, as NSAIDs can. Also, it has no adverse effects on the cardiovascular, central nervous or endocrine systems. Figure 3 provides a simplified diagram of the function of SOD.

L-ergothionine is an intracellular antioxidant naturally occurring in plants and animals, but not synthesized in human bodies: it comes only from dietary sources. The antioxidant properties of L-ergothionein appear to be related to its ability to scavenge reactive oxygen species (free radicals), chelate various metallic cations, activate antioxidant enzymes such as glutathione peroxidase (SeGPx) and manganese superoxide dismutase (Mn SOD) and to inhibit superoxide-generating enzymes such as NADPH- Cytochrome C reductase, and to affect the oxidation of various hemoproteins such as hemoglobin and myoglobin. Because all body tissues depend on these two oxygen carrier molecules, this characteristic is extremely beneficial. [Brummel, M.C., "In Search of a Physiological Function for L-ergothioneine," Med. Hypotheses, 18(4):351-70 (Dec. 1985); Brummel, M.C., "In Search of a Physiological Function for L-ergothioneine, --II," Med. Hypotheses, 30(1):39-48 (Sept. 1989); Han, J.S., "Effects of Various Chemical Compounds on Spontaneous and Hydrogen Peroxide-Induced Reversion in Strain TA104 of *Salmonella typhimurium*," Mutat. Res., 266(2):77-84 (April 1992); Arduini, A., "Possible Mechanism of Inhibition of Nitrite-Induced Oxidation of Oxyhemoglobin by Ergothioneine and Uric Acid," Arch. Biochem. Biophys., 294(2):398-402 (May 1992)].

Collagen Type II also has beneficial effects that help maintain the normal balance between anabolism and catabolism. Specifically, connective tissue diseases may result from autoimmune processes, in which the immune system attacks and catabolizes the individual's own connective tissues as if it were a "foreign invader."

Oral administration of collagen Type II can desensitize the immune system, preventing further attack and normalizing immune responses in these individuals. This decreases catabolic processes in the connective tissues and maximize anabolism. Ingestion of collagen type II presents this molecule to the immune cells in the gut-associated lymphoid tissues (GALT, a.k.a., Peyer's patches). Interactions between the collagen molecule and specific cells within the GALT activates mobile immune cells called T suppressor cells. These cells, in turn, moderate the destructive immune reaction against the individual's own collagen type II (in connective tissues).

Compounds in the tetracycline family include tetracycline, doxycycline, tetracycline analogs, and "tetracycline-like" compounds, and have been used therapeutically for their anti-microbial effects. Current research has focused on "tetracycline-like" compounds which possess insignificant antimicrobial effects, but with anti-catabolic effects. Specifically, "tetracycline-like" compounds are polycyclic compounds that inhibit tissue metalloproteinases which degrade extracellular matrix components including collagen and proteoglycans yet have insubstantial anti-microbial effects. This function of these compounds, as well as other compounds in the tetracycline family, may be related to the ability of these compounds to chelate calcium and zinc ions. For example, doxycycline has been shown to inhibit collagenase activity in articular cartilage.

Although the effects of these compounds have been investigated in isolation, the present invention comprises novel combinations of anabolic agents, anti-catabolic agents and antioxidant agents that maximize beneficial, anabolic effects (healing) and minimize any potential negative effects. In so doing, the present invention provides novel combinations of these agents and anti-oxidant agents, for the protection, treatment and repair of connective tissues in humans and animals.

These compounds have a variety of beneficial effects on animal and human connective tissues, and, because they function via a variety of mechanisms, work well in combination with each other. Although each compound has a number of functions, they can be roughly grouped as: (1) anabolic agents, including glucosamine, SAMe, and AA, which promote growth processes in the body; (2) anti-catabolic agents, such as chondroitin sulfate, pentosan sulfate, collagen type II, tetracyclines and diacerin, which inhibit destructive or catabolic processes; and (3) antioxidants, such as SOD, and L-ergothionine which prevent tissue damage by scavenging toxic oxygen species (free radicals). Naturally, some compounds could be placed in more than one group, by virtue of their overlapping functions. The present invention establishes that combinations of these compounds would work well. Thus, the present invention consists of various combinations of two or more of the following agents: AA, glucosamine, chondroitin sulfate, pentosan, diacerin, S-adenosylmethionine, superoxide dismutase, L-ergothionein, collagen type II, and tetracycline-like compounds.

Examples include, but are not limited to such combinations as: two anabolic agents (e.g., AA and glucosamine); an anabolic agent and an anti-catabolic agent (e.g., glucosamine and collagen type II); an anti-catabolic and an antioxidant (e.g., tetracycline and superoxide dismutase); or combinations of more than two agents (e.g., glucosamine, SAMe and AA).

The following table shows possible combinations of pairs of the compounds discussed above. The letter "X" marks novel combinations of compounds that form the novel compositions of the present invention. The invention also includes combinations of three or more agents of the following compounds in the combinations shown on the table:

Glucosamine

Chondroitin

SAMe

Pentosan

Superoxide Dismutase (SOD)

5 L-Ergothionine

Collagen Type II

Diacerin

Arachadonic Acid

Tetracycline like compounds

10

As explained above, examples of desired combinations are marked by X.

For example, the first X in the first row means a combination of glucosamine and L-ergothionine. The compositions of the present invention additionally comprise any aggregation or addition of the combinations marked by X in any given row or column.

- 15 For example, the compositions disclosed in the first row include combinations of glucosamine plus L-ergothionine plus diacerin, or glucosamine plus diacerin plus tetracycline-like compounds or glucosamine plus L-ergothionine plus diacerin plus AA plus tetracycline-like compounds, and so on. Examples of compositions disclosed in the column designated "Collagen Type II" would include combinations of collagen
- 20 Type II plus SAMe plus pentosan, or collagen Type II plus SAMe plus pentosan plus superoxide dismutase plus L-ergothionine, and so on.

	Superoxide Dismutase (SOD)	L- Ergothionine	Collagen Type II	Diacerin	Arachadonic Acid	Tetracycline like compounds
Glucosamine		X		X	X	X
Chondroitin		X		X	X	X
SAMe	X	X	X	X	X	X
Pentosan	X	X	X	X	X	X
Superoxide Dismutase (SOD)		X	X	X	X	X
L- Ergothionine			X	X	X	X
Collagen Type II				X	X	X
Diacerin					X	X
Arachadonic Acid						X

The present inventors have investigated certain combinations of the above agents and have documented a novel response in several combinations. The effects of certain combinations of chondroitin sulfate, glucosamine, SAMe, arachidonic acid, collagen, pentosan, and superoxide dismutase were studied in cultures of adult bovine cartilage cells in different experiments (see example 2). Certain combinations had an inhibitory effect (hypometabolic) in this particular study. Both stimulatory and inhibitory novel interactions could be beneficial under various disease states. For example, a hypermetabolic state is part of the pathogenesis of some diseases. In such

diseases, an inhibitory (hypometabolic) response would be beneficial to the individual. Future studies are planned to investigate the effects of a range of concentrations in the agents studied under various experimental models. Note that both increases and decreases in biosynthetic activity are novel interactions and could be beneficial to organisms under selected circumstances. For example, many researchers currently believe that osteoarthritis has a hypermetabolic component, especially in the early stages of pathogenesis. Researchers are divided as to whether treatment should focus on agents that stimulate cartilage matrix production, or agents that are inhibitory and therefore make the cartilage environment more hypometabolic, which in turn could have a stabilizing effect on the cartilage tissue.

The compositions of the present invention may be administered via any route, including but not limited to intramuscularly, intravenously, orally, subcutaneously, rectally, topically, transcutaneously, intranasally, and intra-articularly, sublingually, intraperitoneally. Also, any salt of any of the present compounds may be used to aid in absorption, e.g., glucosamine HCl, glucosamine sulfate, sodium chondroitin sulfate, etc. In addition, the composition can be given in all common dosage forms including extended release dosage forms, e.g., pills, tablets, capsules, etc.

The dosage ranges of the compositions of the present invention will vary depending upon the needs of the human or animal to which the compositions are administered. The dosage ranges for the various components of the presently claimed compositions are as follows:

Compound	Daily Dose
Glucosamine	Total dose range: 25 mg to 12 g small animal: 25 mg – 3 g. human: 100 mg – 4 g large animal: 300 mg. – 12 g
Chondroitin sulfate	Total dose range: 15 mg – 12 g small animal: 15 mg – 2 g human: 75 mg – 4 g large animal: 300 mg – 12 g
SAmE	Total dose range: 10 mg – 8 g small animal: 10 mg – 1 g human: 75 mg – 3 g large animal: 400 mg – 8 g
Pentosan	Total dose range: 3 mg to 3 g small animal: 3 mg – 1 g human: 50 mg – 2 g large animal: 100 mg – 3 g
Superoxide dismutase	Total dose range: 3 mg to 6 g (each mg containing > 3000 McCord – Fridovich units) small animal 3 mg – 2 g human: 5 mg – 3 g large animal: 50 mg – 6 g
L-ergothioneine	Total dose range: 50 mg to 25 g

Compound	Daily Dose
	small animal: 50 mg – 10 g human: 50 mg – 15 g large animal: 100 mg – 25 g
Collagen Type II	Total dose range: 0.1 mg to 10 g small animal: 0.1 mg. – 10 g human: 0.1 mg – 7.5 g large animal: 1.0 mg. 10 g
Diacerin	Total dose range: 5 mg to 5 g small animal: 5 mg – 1 g human 20 mg -- 3 g large animal: 50 mg – 5 g
Arachadonic acid	Total dose range: 10 mg to 12 g small animal: 10 mg – 5 g human: 10 mg – 8 g large animal 50 mg – 12 g
Tetracyclines	Total dose range: 1.0 mg to 2 g small animal: 1.0 mg – 1 g human: 2 mg – 1.5 g large animal: 50 mg. – 2 g

Doses are designed to cover the spectrum of body weights of small animals to large animals, with humans in the middle. The following examples are illustrative and do not in any way limit the present invention.

EXAMPLE 1

In our preliminary investigations, surgical instability was induced in the stifle joint of New Zealand white rabbits by modification of the Hulth technique. Post-operatively, animals were exercised for 1 hour daily. Experimental dietary formulas

5 were evaluated for their cartilage stabilizing effect. The standard Harland (Teklad) rabbit diet (control); a standard diet also containing a 2% fungal oil containing 40% AA by weight (Arasco); and a standard diet containing also arachidonic acid and glucosamine/chondroitin were investigated. At 16 weeks, the medial femoral condyles of all rabbits were removed and cartilage degeneration quantitatively

10 evaluated with a modified Mankin histological-histochemical grading system with safranin-O stained slides. Cartilage from all joints with surgical instability exhibited varying degrees of macroscopic degenerative lesions. Our preliminary results indicated that adding arachidonic acid to glucosamine/chondroitin sulfate has the potential to produce a novel interaction in cartilage. This novel interaction has the potential to have

15 a cartilage modulating effect.

EXAMPLE 2

Procedure:

Articular cartilage was resected from human or animal joints aseptically and placed into a large petri dish in a small amount of DMEM/F-12 or F-12. The tissue
5 was diced to 1-2 mm dimensions and transferred to a small culture flask containing 20 mL DMEM or F-12 + 400 u/mL collagenase. The flask was placed on the shaker and incubated overnight.

The cell digest was repeatedly aspirated to increase release of cells. The cell digest was then placed into a 50 mL sterile centrifuge tube and centrifuged in the
10 Beckman at 1000 RPM for 10 minutes. The medium was discarded by pipette and fresh DMEM/F-12 containing 1% FCS added. Depending on the size of the pellet, about 20-40 mL medium was added. Cell counts were determined by haemocytometer and the digest made up to a concentration of 100,000 cells/0.2 mL.

GAG Synthesis:

15 To conduct GAG synthesis, 0.2 mL was aliquoted into each well of a 96 well plate using an 8 channel pipetter and the cells allowed to attach for 24 hours. The media was removed and 0.3 mL of fresh 1% FCS media added for 2 -3 days. On the day of the experiment, the media was removed and the experimental solutions containing 35-sulfate isotope were added. The incubation was continued for 4 hours.
20 Termination: at the end of the incubation period, the labeling media was removed, the cell layer was rinsed repeatedly with cold 0.3 mL DMEM or F-12 (about 5x), and the cell layer was frozen for counting.

Counting of 96 Well Plates:

The cell layer for both the synthesis experiments were heated at 50 degrees after adding 100 ul 1 N NaOH for a period of 2 hours. 200 ul scintillant was added and the plates were placed in the counter. The n sulfate program was used with 1 minute counting time. The data was expressed as CPM/100,000 cells.

5

Evaluation Agent	Indv. Agents: CPM/ 100,000 cells	Sum (CPM)	Agents Combined (CPM)	Difference (CPM)
ChSO4-L	64			
AA	70	134	18	-116
ChSO4-H	50			
AA	70	120	81	-39
Glu-H	117			
AA	70	187	16	-177
1%Sam	123			
10Paleos	86	209	62	-147
1%Sam	123			
1Paleos	74	197	80	-117

Evaluation Agent	Indv. Agents: CPM/ 100,000 cells	Sum (CPM)	Agents Combined (CPM)	Difference (CPM)
3%Sam	42			
1Paleos	74	116	100	-16
3%Sam	42			
10Paleos	86	128	83	-45
3%Sam	42			
Collagen	118	160	90	-70
3%Sam	42			
AA	70	112	104	-8
AA	70			
10Pentos	76	146	106	-40
Collagen	70			
10Paleos	86	156	82	-74
Collagen	118			
10 Pentos	76	194	65	-129

Evaluation Agent	Indv. Agents: CPM/ 100,000 cells	Sum (CPM)	Agents Combined (CPM)	Difference (CPM)
Collagen	118			
10 Paleos	86	204	77	-127

ChSO₄ = Chondroitin

AA = Arachadonic Acid

SAMe = S-adenosymethionine

5 Paleos = SOD

Collagen = Collagen

Pentos = Pentosan

H = High concentration

L = Low conentration

In this model, at the concentrations studied, the representative combinations had an inhibitory (hypometabolic) effect in this particular study. This hypometabolic effect could be beneficial under various disease states, indeed both stimulatory and inhibitory novel interactions could be beneficial under various disease states. For example, a hypermetabolic state is part of the pathogenesis of some diseases. In such diseases, an inhibitory (hypometabolic) response would be beneficial to the individual. Future studies are planned to investigate the effects of a range of concentrations in the agents studied under various experimental models. Note that both increases and decreases in biosynthetic activity are novel interactions and could be beneficial to organisms under selected circumstances. For example, many researchers currently believe that osteoarthritis has a hypermetabolic component, especially in the early stages of pathogenesis. Researchers are divided as to whether treatment should focus on agents that stimulate cartilage matrix production, or agents that are inhibitory and therefore make the cartilage environment more hypometabolic, which in turn could have a stabilizing effect on the cartilage tissue.

EXAMPLE 3

A 4 year child has juvenile rheumatoid arthritis in which the immune system inappropriately targets endogenous connective tissues with antibodies against native collagen type II. The resulting inflammation and degradation of cartilage causes pain and dysfunction in the synovial joints. Present treatments include corticosteroids which non-selectively suppress the immune system, thus leaving the body vulnerable to infectious disease, or methotrexate, which inhibits DNA synthesis, repair, and cellular replication, thus affecting not only the immune system but also intestinal mucosa, and the bone marrow. This child is given 2 mg of collagen type II daily, and SOD 10 mg

daily. The collagen decreases the inappropriate immune attack, and the SOD inactivates destructive free radicals that damage cells. By preventing cellular damage, the SOD helps maximize the normal function of joint tissue cells. This combination has no harmful side effects at therapeutic doses and is a beneficial addition to existing
5 therapies for rheumatoid arthritis.

EXAMPLE 4

A 6 yr old thoroughbred race horse has neutrophilic inflammation of the carpus. In this condition, trauma to the tissues of the joint injures cells and therefore
10 results in liberation of cytokines which attract large numbers of neutrophils into the synovial space. This response is beneficial in cases of sepsis, but in non-septic conditions the neutrophils provide no useful service to the animal. Indeed, because neutrophils produce various degradative compounds, including superoxide molecules, their presence in the joint contributes to a vicious cycle of inflammation, tissue
15 damage, and increased inflammation. Currently this condition is treated with nonsteroidal antiinflammatory drugs, which suppress prostaglandin synthesis and therefore have many side effects. This horse is given a mixture of diacerin 100 mg, pentosan 200 mg and SAME, 1000 mg. The diacerin and pentosan both inhibit chemotaxis (the attraction of white blood cells into the affected area) and thus reduce
20 the numbers of neutrophils in the joint. Additionally, pentosan stimulates the synthesis of synovial fluid and thus supports normal function of the joint. Diacerin inhibits superoxide production; since superoxide production is one of the mechanisms through which neutrophils have their harmful effects, this action of diacerin is obviously beneficial. SAME supports the structure and function of cell membranes, and therefore
25 helps repair injured joint tissue cells thus blocking the events that start the harmful

inflammation. This combination has no harmful side effects at therapeutic doses and is a great improvement over existing therapies

One of skill in the art would understand that combinations of the

5 compounds taught by the present invention would act synergistically. For example, it is understood that glucosamine has stimulatory effects on chondrocyte metabolism which, by itself, aids in ameliorating diseases of cartilage degradation. However, an increase in cell metabolism can also produce an increase in free-radical production, as a natural by-product of oxidative phosphorylation. The increase in free radical

10 production would dilute the beneficial effects of the glucosamine administration. By combining L-ergothioneine with glucosamine, one would expect an increase in metabolism and a reduction in free-radical damage, providing for a greater benefit than if compounds leading to one of these effects were provided. Therefore, one of skill in the art, based on the teaching of the present invention, would understand that

15 combining glucosamine with L-ergothioneine would be more beneficial than providing either alone. The synergy that exists between certain compounds in the present invention also enables the use of lower doses of each compound. Although these compounds have a quite safe, there may be a potential for side effects. For example, large doses of glucosamine sulfate or chondroitin sulfate can cause gastrointestinal

20 disturbances in some individuals. In addition, these compounds are costly; for these reasons, the ability to minimize the dose and still achieve beneficial effects is desirable.

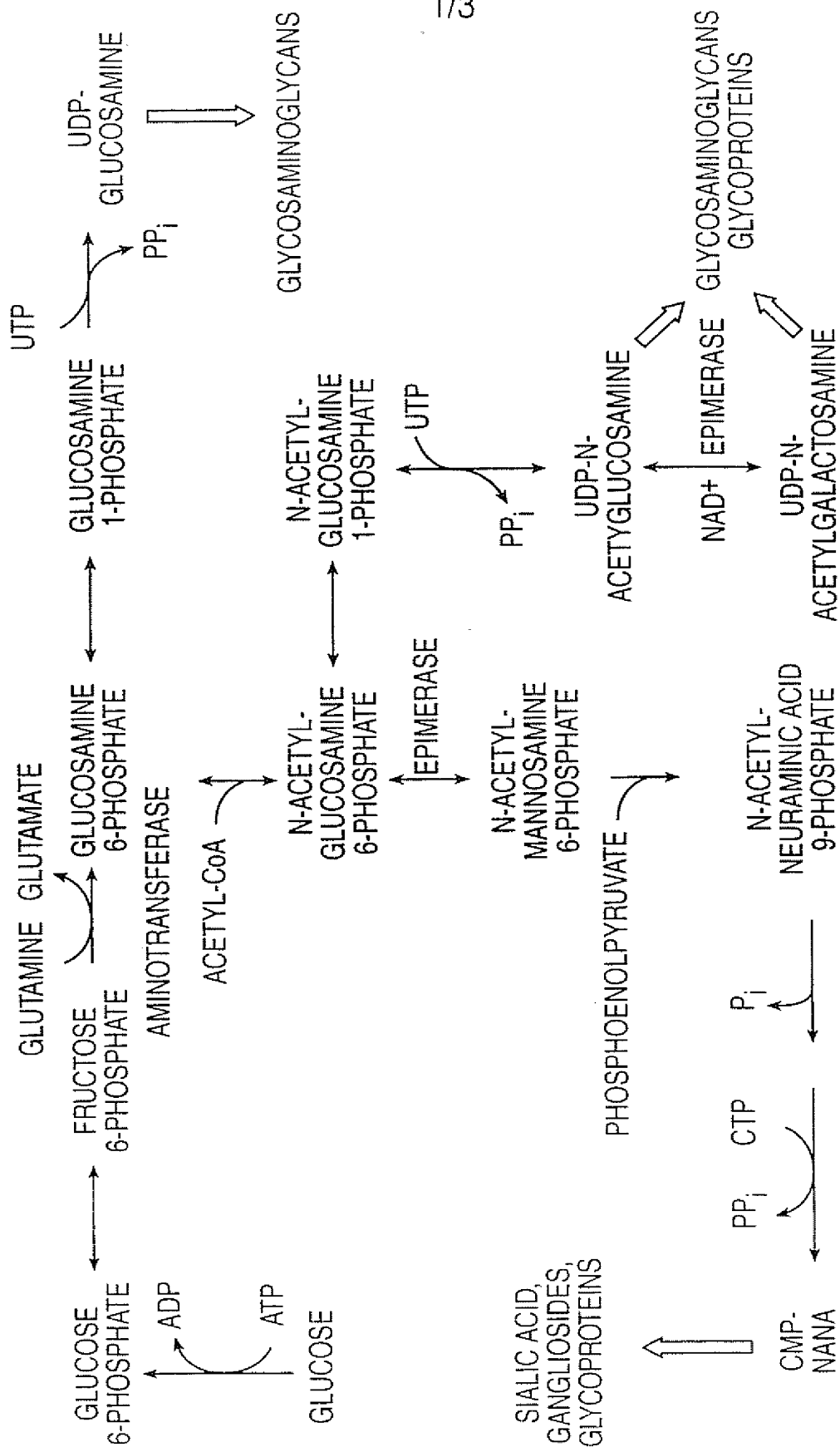
Many modifications may be made without departing from the basic spirit of the present invention. Accordingly, it will be appreciated by those skilled in the art that within the scope of the appended claims, the invention may be practiced other than has been specifically described herein. Hence, the attached claims are intended to cover the
5 invention embodied in the claims and substantial equivalents thereto.

WE CLAIM:

1. A composition for the treatment, repair or prevention of damage to connective tissue comprising an aminosugar and one or more compounds selected from the group consisting of L-ergothionine,
5 diacerin, arachadonic acid, and tetracycline-like compounds.
2. A composition for the treatment, repair or prevention of damage to connective tissue comprising a GAG and one or more compounds selected from the group consisting of L-ergothionine, diacerin, arachadonic acid, and tetracycline-like compounds.
- 10 3. A composition for the treatment, repair or prevention of damage to connective tissue comprising SAME and one or more compounds selected from the group consisting of SOD, L-ergothionine, collagen type II, diacerin, arachadonic acid, and tetracycline-like compounds.
- 15 4. A composition for the treatment, repair or prevention of damage to connective tissue comprising pentosan and one or more compounds selected from the group consisting of SOD, L-ergothionine, collagen type II, diacerin, arachadonic acid, and tetracycline-like compounds.
- 20 5. A composition for the treatment, repair or prevention of damage to connective tissue comprising a GAG-like compound and one or more compounds selected from the group consisting of SOD, L-ergothionine, collagen type II, diacerin, arachadonic acid, and tetracycline-like compounds.
6. A composition for the treatment, repair or prevention of damage to connective tissue comprising SOD and one or more compounds selected

from the group consisting of L-ergothionine, collagen type II, diacerin, arachadonic acid, and tetracycline-like compounds.

- 5
7. A composition for the treatment, repair or prevention of damage to connective tissue comprising L-ergothionine and one or more compounds selected from the group consisting of collagen type II, diacerin, arachadonic acid, and tetracycline-like compounds.
- 10
8. A composition for the treatment, repair or prevention of damage to connective tissue comprising collagen type II and one or more compounds selected from the group consisting of diacerin, arachadonic acid, and tetracycline-like compounds.
- 15
9. A composition for the treatment, repair or prevention of damage to connective tissue comprising diacerin and one or more compounds selected from the group consisting of arachadonic acid, and tetracycline-like compounds.
- 20
10. A composition for the treatment, repair or prevention of damage to connective tissue comprising arachadonic acid and tetracycline-like compounds.
11. A method of preventing, treating or repairing damage to connective tissue in humans and animals comprising administering the compositions of any one of claims 1-10 to a human or animal in need thereof.



THE SYNTHESIS OF GLYCOSAMINOGLYCANS FROM GLUCOSAMINE

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G
L

2/3

THE SYNTHESIS OF S-ADENOSYLMETHIONINE

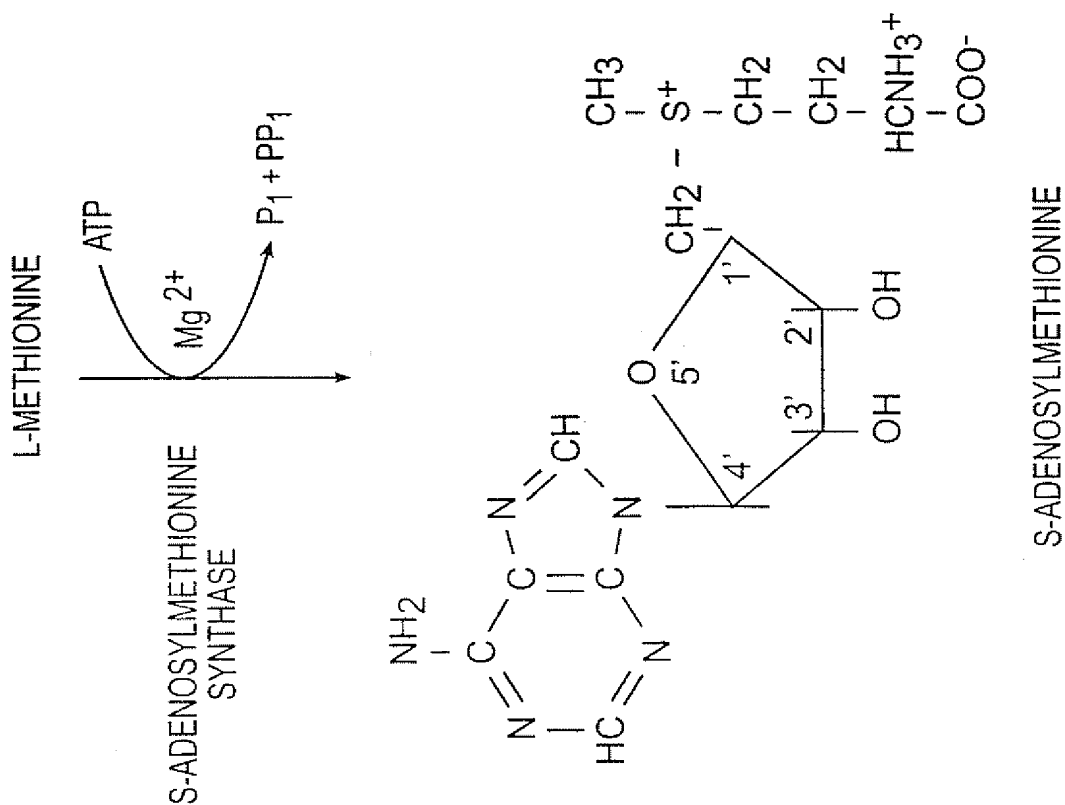
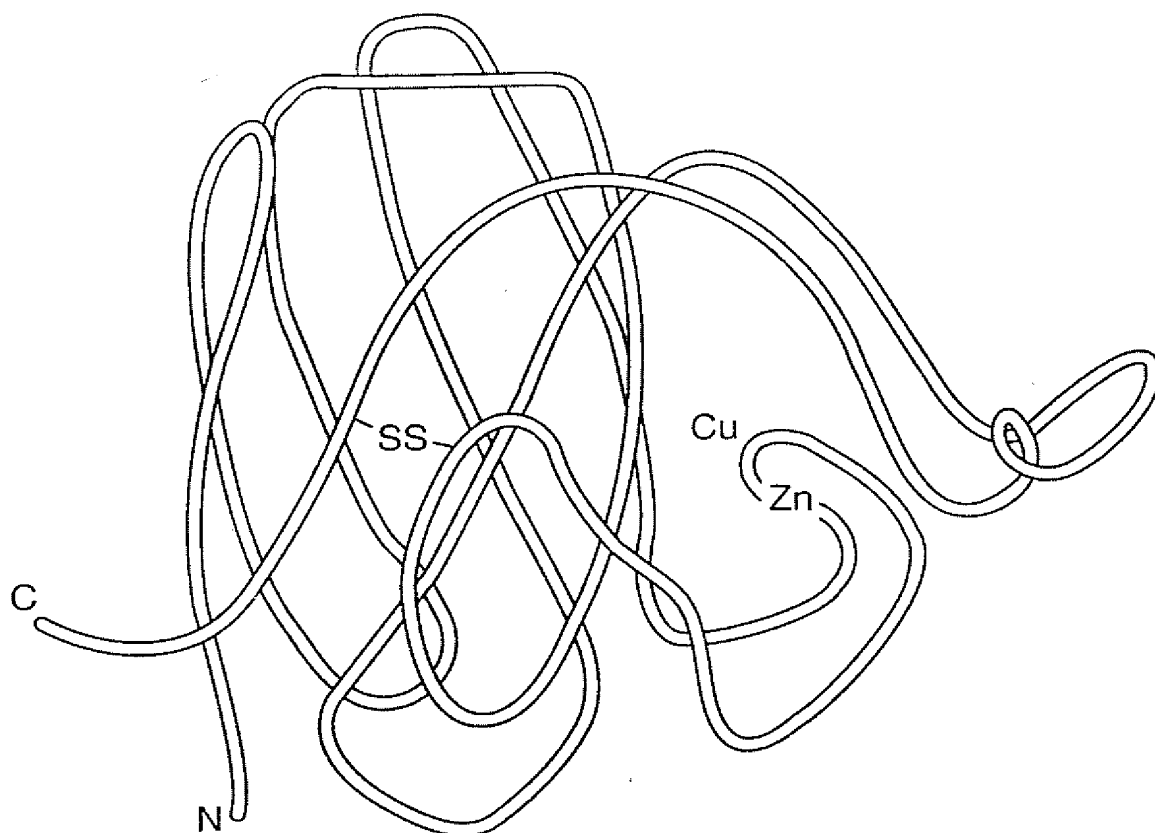


FIG. 2

3/3



SIMPLIFIED DIAGRAM OF THE THREE-DIMENSIONAL STRUCTURE
OF A SUBUNIT OF BOVINE SUPEROXIDE DISMUTASE

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/03019

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : A61K 35/34, 31/65

US CL : 424/548; 514/152

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 424/548; 514/152

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS, STN: COMPOUNDS AND METHODS OF USE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y,P	US 5,770,209 A (GROTENDORST ET AL) 23 June 1998, see entire document.	1-11
Y	US 4,925,833 A (McNAMARA ET AL) 15 May 1990, see entire document	1-11
Y	US 5,258,371 A (GOLUB ET AL) 02 November 1993, see entire document	1-11

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
A document defining the general state of the art which is not considered to be of particular relevance	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
E earlier document published on or after the international filing date	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*Z* document member of the same patent family
O document referring to an oral disclosure, use, exhibition or other means	
P document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

08 APRIL 1999

Date of mailing of the international search report

27 APR 1999

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